International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 1, Feb 2018, 1119-1126

Original Article

DESIGN AND SIMULATION OF CONNECTING RODS WITH SEVERAL TEST CASES USING AL ALLOYS AND HIGH TENSILE STEEL

T. SATHISH[1] & A. MUTHULAKSHMANAN[2]

[1]*Dean (R & D), Vesta Research Institute, Aranthangi, Tamil Nadu, India*

[2]*Associate Professor, Sri Sunflower College of Engineering and Technology, Andhra Pradesh, India*

ABSTRACT

The connecting rods designed recently are made from cast iron and carbon steel, which possess less tensile strength, toughness and durability. To improve such concern, this work aims in designing and analyzing the connecting rod with suitable dimensions over the crank end and piston end to be fitted in the two wheeler engine. The resultant material is tested under four cases with various materials, namely, Aluminium alloys and AISI High Tensile Steel 4340. Finite element analysis is carried out with the constructed material to test its tensile strength, stiffness and weight under various loads. In addition to this, the stress and strain measurement is considered to prove its reliability. All the test results show that the proposed material is reliable in terms of the material under different test cases.

KEYWORDS: Connecting Rod, Stress Test, Strain Test, Weight Comparison & Fatigue Calculation

Received: Dec 30, 2017**; Accepted:** Jan 19, 2018**; Published:** Feb 05, 2018**; Paper Id.:** IJMPERDFEB2018133

1. INTRODUCTION

The objective of the study is to optimize the connecting rods with various designs and analysis using finite element analysis with various materials. This work mainly aims to reduce the stress and strain undergone by the materials used in connecting rods. This work provides a better alternative design for the connecting rods in the two wheelers. The present study considers the Aluminum alloy and AISI High Tensile Steel 4340 material for testing the designed connecting rod. Yang et al., (1996) optimized the shape of connecting rod using an approach that gets subjected to cycling load. This includes the inertia load or gas load in the form of one extreme/peak load offered to the piston assembly mass similar to the other extreme. Montazersadgh F. H et al., (2007) analysed dynamically the connecting rod and the finite elemental analysis helped in identifying the critical stress location in the connecting rod.

Naga Malleshwara Rao (2013) followed similar principle to design the connecting rod, but it gets designed with four different materials: Ti, Al, Genetic steel and cast iron.

Pathade et al., (2012) designed connecting rod to investigate the major stress associated with it. This stress is considered as the combination of the bending stress and axial load. The connecting rod with Al and steel alloy is analytically designed by Tukaram S et al. (2013). The research is carried out to find the differences between the weight and the conmises stress between the materials. The optimization to improve the design of connecting rods with 4 stroke design is carried to with two different materials by Marthanapalli Hari Priya et al., (2013). Further analysis is carried out to find the weight and cost reduction and it concludes that the Al360 material is safe in terms of its stress value and weight reduction.

Vegi and Vegi, (2013) proposed a research on design and analysis on the connecting rod, which is manufactured with the carbon steel. Shahrukh Shamim,(2014) investigated the similar connecting rod for similar analysis, however, the material used for the rod is made of E-glass/ E-proxy and Aluminium composite reinforced with carbon nano tubes. Savanoor et al. (2014) used two different Al alloys for investigating the con-mises stress and deformation with forged steel. It is found that the results of the Al5083 have less stress and weight and the section modulus is found enough that reduces the bending stress associated with inertia force. Similarly, MohdNawajish et al. (2015) obtained only 20% weight reduction with fracture split able steel forged material. Agarwal et al. (2015) utilized C steel or AL with Be and Mg alloy. The results conclude that the Be alloy is found with ultimate strength than other materials and it possess less maximum displacement and the vibration is found to be minimum. Finally, a comparative study (Mohd Nawajish et al. (2015)) between the connecting rods of various materials like Al360, Be alloy 25, Ti alloy is taken place to find the better samples.

The origination of the paper is as follows: Section 2 provides the calculations required to construct the connecting rod. Section 3 discusses the proposed work and finite element analysis is carried out in section 4. Section 5 discusses the results and section 6 concludes the entire work.

2. PROPOSED DESIGN

The proposed study involves following design considerations. Initially, the calculations to select the material and its properties are studied based on the design calculations. Then the connecting rod is modeled as per the dimensions calculated with the required calculations. Finite element analysis is carried out to measure the effectiveness of the proposed design with various material calculated previously. Then the results are consolidated based on several constraints, which is discussed in following sections. Finally, the results are compared with different material based on its weight, stiffness and other metrics, the dimension of the connecting rod is shown in Figure 1.

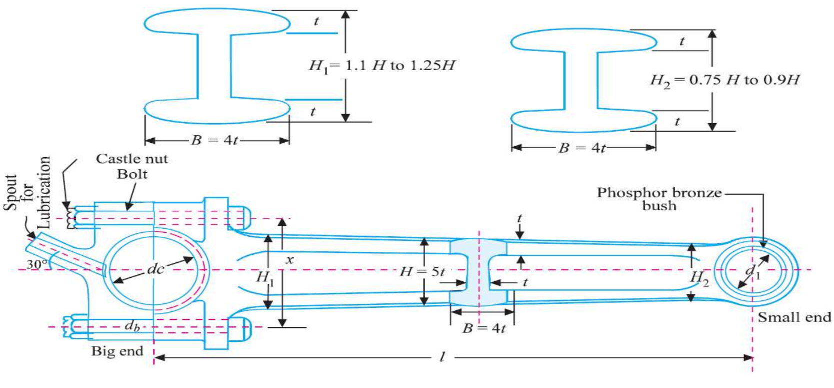


Figure 1: Connecting Rod Dimensions

1.1. Pressure on Connecting Rod

The normal pressure (P_o) on the contact surface is calculated as: $P = P_o \cos\theta$. The tensile load on the contact surface is: $P_o = P_t / r\, t\, (\pi/2)$ and the compressive load is $P_o = P_c / r\, t$. Here, the crank angle, θ is 0^o, r is the crank, (r_{ps}) or piston end (r_{cp}) radius and t is the thickness l_{ps} and l_{cp} connecting rod. The axial load (F_g) for compression (P_c) and the tension (P_t) load is 5391 N.

2.2. Thickness of Big End Cap

Here, the thickness is measured by considering the cap as a beam structure, which is freed supported at its centre. The beam is now loaded with the inertial force at the dead centre at its top on the surface of the exhaust stroke i.e. considering $F_I$if θ is 0. Here, the load act between the uniform distributed and central concentrated load and the bending moment (maximum) on the cap is considered as $M_C = F_I * X/6$, Where, X is considered as the distance between center of the load.

$\sigma_b = M_C / Z_C$

Substituting the above values in σ_b, 120 = (25085 x 6)/39.3 $(t_c)^2$; where, t_c = 5.6mm.

Where, t_c represents the cap thickness, b_c represents the cap width measured in mm, which is equal to l_{cp} with value 39.3mm and $\sigma_b$represents the bending stress of the cap measured in MPa and the value is assumed as 120 MPa. Similarly, the properties of various materials for the proposed study is shown in table 2.

Table 1: Dimensions of Connecting Rod

Parameters	Dimensions in 'mm'
Connecting rod - Length	116
Crank end - Inner diameter	46.02
Crank end - Outer diameter	56.55
Piston end - Inner diameter	16.75
Piston end - Outer diameter	22.11
Bolt diameter	5
Big end cap - Thickness	5.6

Table 2: Loading Conditions

	Compressive Load	Tensile Load
Piston End	17.33 MPa	19.11 MPa
Crank End	4.03 MPa	4.444 MPa

Table 3: Material Properties

Material Name and Properties	Al 7075 Alloy	Al 6061 Alloy	High Tensile Steel AISI 4340
Yield Tensile Strength (MPa)	510	270	730
Ultimate Tensile Strength(MPa)	580	310	1080
Modulus of Elasticity (GPa)	80	80	210
Endurance Limit (MPa)	160	97	540
Density (g/cm^3)	2.81	2.7	7.85
Poisson's Ratio	0.33	0.33	0.3

Dimensions of Connecting Rod: The dimensions of the connecting rod for various materials are shown in table.4.

Table 4: Dimensions of the Connecting Rod Subjected to Various Materials

Aluminum 7075 Alloy		
Compressive Yield Strength	**(σ_C)**	**510 MPa**
By Rankine formula, $F_B = [\sigma_C \times A]/(1+a[L/\ Kxx]^2)$; 32346 = [510x10^{6}x11t^2] / (1+0.00016 [0.116/1.78t]^2); t = 2.5 mm		
Width	B = 4t	10.000 mm
Height	H = 5t	12.500 mm
Area	A = 11t^2	68.750 mm^2

Table 4: Contd.,		
Height near Piston end	H_1 = (0.75 to 0.9)H H_1 = 0.9 H	11.250 mm
Height near Crank end	H_2 = (1.1 to 1.25)H H_2 = 1.25 H	15.625 mm
Aluminum 6061 Alloy		
Compressive yield strength	**(σ_C)**	**270 MPa**
By Rankine formula, $F_B = [\sigma_C \times A]/(1+a[L/\ K_{xx}]\ ^2)$; 32346 = $[270x10^6x11t^2]$ / (1+0.00016 $[0.116/1.78t]\ ^2$); t = 3.3960 mm		
Width	B = 4t	13.5840 mm
Height	H = 5t	16.980 mm
Area	A = $11t^2$	126.860 mm^2
Height near Piston end	H_1 = (0.75 to 0.9)H H_1 = 0.9 H	15.280 mm
Height near Crank end	H_2 = (1.1 to 1.25)H H_2 = 1.25 H	21.225 mm
High Strength Steel 4340		
Compressive yield strength	**(σ_C)**	**730 MPa**
By Rankine formula, $F_B = [\sigma_C \times A]/(1+a[L/\ Kxx]\ ^2)$; 32346 = $[730x10^6x11t^2]/(1+0.00016\ [0.116/1.78t]\ ^2)$; t = 2.15 mm		
Width	B = 4t	8.6 mm
Height	H = 5t	10.75 mm
Area	A = $11t^2$	50.85 mm^2
Height near Piston end	H_1 = (0.75 to 0.9)H H_1 = 0.9 H	9.675 mm
Height near Crank end	H_2 = (1.1 to 1.25)H H_2 = 1.25 H	13.44 m

3. FINITE ELEMENT ANALYSIS

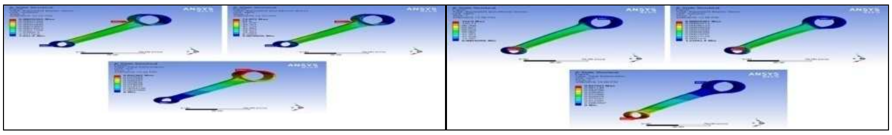
The Finite Element Analysis is carried out with ANSYS 15 as a platform for measuring the performance of the connecting rod that considers the entire loading conditions. The study considers mainly the stress analysis to calculate the safety factor for the connection rod in the vehicle. The Finite Element Analysis on the connecting rod is carried out with tensile test and compressive load test. Moreover, this study considers 4 different cases, which are analyzed using the software. All the cases are analyzed with load applied over the crank and restrained at piston end. Similarly for others, the load is applied at piston and restrained at the crank end. The 4 conditions for testing includes: Compressive Load at Crank End, Tensile load at Crank End, Compressive Load at Piston End and Tensile Load at Piston End.

The four cases are discussed in the following section with various results of connecting rod as shown in Figure 2 (a) and (b). *Case 1:* The Piston End is made fixed and the Compressive Load is applied at Crank End. *Case 2:* The Crank End is made fixed and the Compressive Load is applied at Piston End. *Case 3:* The Piston End is made fixed and the Tensile Load is applied at Crank End. *Case 4:* The Crank End is made fixed and the Tensile Load is applied at Piston End.

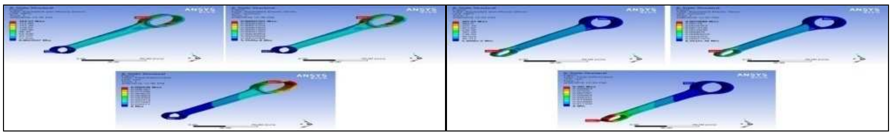
The loading conditions of connecting rod as per the four different cases are shown in Figure 3-5. The results of von-mises stress, strain and total deformation for case 1, 2, 3 and 4 is shown for different materials in Figure 3, Figure 4 and Figure 5, respectively. The connecting rods under various conditions are tested with the standard materials like Al 6061, AISI 4340 and Al 7075.

(a) **(b)**

Figure 2: a) Connecting Rod Model; b) Meshed Model of Connecting Rod

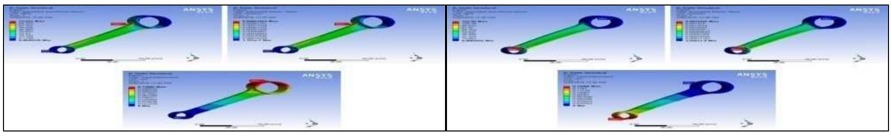


Case 1 **Case 2**

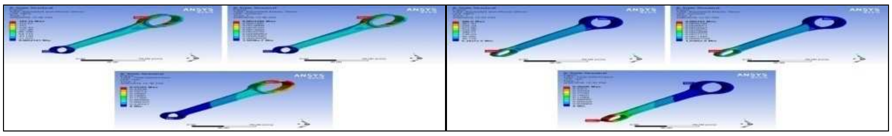


Case 3 **Case 4**

Figure 3: Results for Material AISI 4340

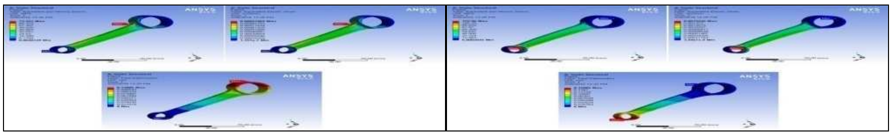


Case 1 **Case 2**

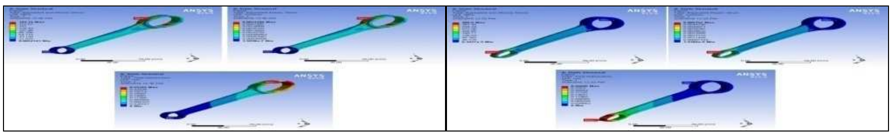


Case 3 **Case 4**

Figure 4: Results for Material Al 7075



Case 1 **Case 2**



Case 3 **Case 4**

Figure 5: Results for Material Al 6061

4. RESULTS AND DISCUSSIONS

Here, the connecting rod is tested under various materials based on different test, which are shown below. The FOS and the fatigue test for the connecting rod under various materials are shown in Table.5. The following calculations are

required to evaluate the measurements of the rod.

Table 5: Measured Value of Various Material Compositions

		Aluminum 7075 Alloy	Aluminum 6061 Alloy	AISI 4340 Steel
Mean stress	σ_m	36.777 MPa	36.777 MPa	37.0143 MPa
Yield stress	σ_v	36.773 MPa	36.773 MPa	37.0107 MPa
Factor of safety	f. s	3.310	1.94	8.4
s. f	s. f	154 MPa	92.66 MPa	436 MPa
Endurance limit for variable axial stress	σ'_e	153.6 MPa	93.12 MPa	518 MPa
No. of cycles	N	1090 x 10^3	1031 x 10^3	6646 x 10^3

The weight and stiffness measures of the connecting rod under various materials are shown in Table.6. The weight is calculated as volume x density and the stiffness is measured as weight/deformation. With such calculation, the body volume is calculated as 34095 mm^3

Table 6: Weight and Stiffness Measure of Various Material Compositions Over Connecting Rod

Parameter	Dimension		
	Al 7075	Al 6061	AISI 4340
Density	2.81 g/cm^3	2.7 g/cm^3	7.85 g/cm^3
Weight	96 grams	92 grams	268 grams
Stiffness	866 g/mm	830 g/mm	6336 m

5. CONCLUSIONS

The analysis of the connecting rod to be placed in the engine of two wheelers is finally constructed. The result of the finite element analysis proves the betterment of the design under various test cases with Aluminium 7075 and 6061 alloy and AISI 4340 steel. Out of which, the fourth test case proved well in terms of better achievable and satisfactory results under all loading conditions . It is seen that the equivalent stresses of the Al 6061 is found slightly less than AISI 4340 Steel. The weights of the Al 6061 have the maximum weights when compared with other two materials, however, the weight reduction percentage is achieved around 65.7%. The deformation in standard AISI 4340 Steel material is minimum than Al 7075 and Al 6061 alloy, tested under various loading conditions over the four test cases. Finally, the stiffness test with AISI 4340 Steel is 6336 g/mm, which is high when compared with other Al Alloys. Also, the fatigue cycle calculation shows that the standard AISI 4340 steel material is higher than other Al alloys. However, the stress associated standard AISI 4340 steel increase slightly with loading conditions. This proves that the design consideration has promising results, which proves the present study to be effective for engine design.

REFERENCES

1. *Agarwal P., Gupta, A. and Saxena, V., A Comparative Study of Different Materials of Connecting Rod: A Review.*
2. *Leela Krishna Vegi and Venu Gopal Vegi, "Design and Analysis of Connecting Rod Using Forged Steel", IJSER, Vol. 4, Issue 6, June 2013.*
3. *Marthanapalli Hari Priya, K. Manohar Reddy, "Materialized Optimization of Connecting Rod for Four Stroke Single Cylinder Engine", IJCER, Vol. 3, Issue 10, October 2013.*
4. *MohdNawajish, MohdNaimuddin and Mayank, "A Comparative Study and Analysis of Connecting Rod", IJETMAS, Vol. 3,*

March 2015.

5. *Montazersadgh, F. H. and Fatemi, A., 2007, “Dynamic Load and Stress Analysis of a Crankshaft,” SAE Technical Paper No. 2007- 01-0258, Society of Automotive Engineers, Warrendale, PA, USA.*
6. *Qasim Bader, Effect of V Shape Notch Location on Fatigue Life in Steel Beam Made of Carbon Steel Alloys with Different Content of Carbon, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 4, Issue 4, July - August 2014, pp. 69-78*
7. *Naga Malleshwara Rao, “Design Optimization and Analysis of a Connecting Rod using ANSYS”, IJSR, Vol. 2, Issue 7, July 2013.*
8. *Savanoor, R. A., Patil, A., Patil, R. and Rodagi, A., 2014. Finite element analysis of IC engine connecting rod by ansys. International journal of mechanical engineering and robotic research, 3(3).*
9. *SavanoorR. A., AbhishekPatil, RakeshPatil and Amit Rodagi, “Finite Element Analysis of IC Engine Connecting Rod by Ansys”, IJMERR, Vol. 3, July 2014.*
10. *Shahrukh Shamim, “Design and Comparative Analysis of Connecting Rod using Finite Element Method” IJERT, Vol. 3, Issue 9, September 2014.*
11. *Wafaa A. Ghanem et al., Electrochemical Behavior and Effect of Temperature on Dezincification of Cu-Zn Alloys in Brine Solutions, International Journal of Metallurgical & Materials Science and Engineering (IJMMSE), Volume 6, Issue 4, September - October 2016, pp. 1-16*
12. *Tukaram S. Sarkate, Sachin P. Washimkar, Sachin S. Dhulekar, “Optimization of Steel Connecting Rod by Aluminium Connecting Rod Using Finite Element Analysis”, IJRAET, Vol. 1, Issue 1, October, 2013.*
13. *Vivek C. Pathade, BhumeshwarPatle, Ajay N. Ingale, “Stress Analysis of I. C. Engine Connecting Rod by FEM”, IJEIT, Vol. 1, Issue 3, March 2012.*
14. *Yang, P. C., Yang, H. T. and Huang, C. L., 1996. Solving the unit commitment problem with a genetic algorithm through a constraint satisfaction technique. Electric Power Systems Research, 37(1), pp.55-65.*